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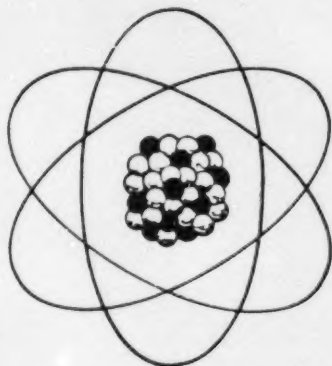
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ABSTRACT

This sixth in a series of ten modules for a course titled Welding Inspection describes procedures review, process monitoring, and weld defect analysis. The module follows a typical format that includes the following sections: (1) introduction, (2) module prerequisites, (3) objectives, (4) notes to instructor/student, (5) subject matter, (6) materials needed, (7) procedures, (8) data table, (9) reference materials, (10) test. (The course is one of fifteen technical courses for the second year of a two-year postsecondary curriculum in Nuclear Quality Assurance/Quality Control Technology.) (LRA)

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COURSE 28 WELDING INSPECTION

MODULE 28-6 Process Controls



GENERAL PHYSICS CORPORATION
Columbia, Maryland

CE 024 266



COURSE MODULES

COURSE 28 WELDING INSPECTION

Module 28-1	Welding Fundamentals and Processes
Module 28-2	Shielded Metal Arc and Oxyacetylene Welding
Module 28-3	Tungsten Inert Gas (TIG), Metal Inert Gas (MIG) and Submerged Arc Welding
Module 28-4	Weld Joint Verification
Module 28-5	Qualifications
Module 28-6	Process Controls
Module 28-7	Acceptance Inspection
Module 28-8	Filler Metal Control
Module 28-9	Weld Repair Control
Module 28-10	Records



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This module was prepared for General Physics Corporation by John Espy of General Physics.



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INTRODUCTION

The first five modules of this course have discussed the fundamentals of welding. It is evident that a welding program is complex, particularly when it is applied to construction or maintenance cycles employing hundreds of welders. While completed welds are examined as described in Module 28-7, examination of final welds do not provide total assurance of weld quality. Final examinations determine if welding defects are present, but it does not measure the chemical and mechanical properties of the weld. As described in Module 28-5, these properties are assumed to be correct if qualified procedures are followed by qualified welders. Use of qualified procedures by qualified welders is assured by in-process checks.

The need for in-process checks of welding is recognized by Criterion IX of Appendix B to 10CFR50. This criterion reads as follows:

"Measures shall be established to assure that special processes, including welding, heat treating, and nondestructive testing, are controlled and accomplished by qualified personnel using qualified procedures in accordance with applicable codes, standards, specifications, criteria, and other special requirements."

This criterion is met by the combination of written procedures and process control. Written procedures delineate responsibilities and authorities for the welding program. They include the welding procedure specification and instructions for procedure and welder qualification. If the procedures are adequate and if compliance with procedures is achieved, weld quality can be assured. Process control assures that procedures are adequate and are followed.

Process control is typically achieved by procedures review, process monitoring, and weld defect analysis. The QA/QC Technician is normally responsible for process monitoring and may also participate in procedures review and weld defect analysis. This module describes these functions.



MODULE PREREQUISITES

All previous Course 28 modules shall be complete before proceeding to this module



OBJECTIVES

Upon completion of this module, the student/trainee shall be able to:

1. Name five types of inspections associated with monitoring of welding processes, describe how each is conducted, and state the purpose of each.
2. Demonstrate the ability to read and interpret a post weld heat treatment chart.
3. State the objective of welding process monitoring and describe four key features which should be contained by a welding process monitoring program.
4. Name and discuss three factors which should be considered in establishing the base line frequency for monitoring welding processes.

5. Name seven elements of the administrative procedure for the welding process monitoring program and describe the role of each.
6. Name four elements of weld defect analysis and describe the role of each.
7. Relate the effectiveness of weld defect analysis to welding production rate, timeliness of analysis, and method of analysis.



NOTES TO INSTRUCTOR / STUDENT

Advance preparation will be needed for the exercises suggested by this module. In particular, example heat treatment charts will be necessary to develop skills in interpreting heat treatment charts. Nearby industries and power plants may be willing to provide example heat treatment charts.



SUBJECT MATTER

DEFINITIONS

- Review - A deliberately critical examination to determine compliance with a standard.
- Inspection - Examination, observation or measurement to determine conformance of materials, supplies, components, parts, appurtenances, systems, personnel performance, procedures, processes, or structure to predetermined requirements.
- Monitoring - Inspection of personnel performance, procedures, and processes on a job site while the process is in operation.
- Defect Analysis - A planned review of data to determine the effectiveness of a process in terms of defect rate or other indication of acceptance.

WELDING CONTROL PROGRAM

Written procedures describe the responsibilities and authorities within an organization for implementing the welding program. These procedures typically assign responsibilities to three departments: Welding Engineering, Welding (or Maintenance), and Quality Assurance. These responsibilities are typically distributed as follows:

Welding Engineering Department Responsibilities are as follows:

- define welding procedure qualification requirements
- define welder qualification requirements
- prepare welding procedure specifications
- prepare requisitions for procurement of materials and equipment

- prepare welding job packages consisting of all necessary drawings, sketches, and welding procedures to provide instructions on what to weld, when to weld, how to weld, and special instructions such as for cleaning, grinding, heat treating, etc.
- review nondestructive examination procedures
- disposition welding defects

Welding (or Maintenance) Department Responsibilities are as follows:

- perform welding procedure qualifications
- perform welder qualifications
- perform shop or field welding (original and repair)
- maintain welder requalifications
- maintain welding equipment
- prepare and implement supplementary instructions for good welding practices such as distortion control, cleaning, fit-up, temperature measuring practices, control of filler material on the job, control of hand tools such as brushes, grinders, picks, etc.

Quality Assurance Department Responsibilities are as follows:

- prepare the company's welding program control procedure
- review procedures, instructions, and requisitions prepared by Welding Engineering and Welding Departments
- review welding job packages and identify the acceptance inspections to be performed (NOTE: identification of acceptance inspections is sometimes performed by Welding Engineering and approved by Quality Assurance)
- prepare nondestructive examination procedures
- prepare or approve records formats for procedure and welder qualifications and for examination of shop and field welds

- establish and implement a weld filler material control program that issues to welders only the correct filler material (NOTE: this function is sometimes assigned to another department with Quality Assurance having a monitoring role)
- provide the qualified personnel for nondestructive examination of welds
- assure an adequate system exists for collection and storage of welding records
- develop and implement a process monitoring program

Execution of the above responsibilities should provide for adequate procedures. Each type of procedure receives an independent review prior to its use. The independent review ensures that the procedures comply with governing welding codes and regulatory requirements. Assurance of compliance with the procedures is provided by the process monitoring function.

INSPECTIONS OF PROGRESS MONITORING AND ASSOCIATED ACCEPTANCE CRITERIA

Within the process monitoring program, inspections are performed to determine compliance with procedural requirements. In this regard, inspections are performed for cleanliness, fit-up, welding data, post weld heat treatment and compliance with welding program procedures. Each of these types of inspections are discussed below.

Inspection for Cleanliness

Cleanliness inspections are visual inspections that are performed immediately prior to, and shortly after weld joint fit-up. Cleanliness of interpasses may also be inspected.

Prior to commencement of welding, cleanliness inspections ascertain that the weld end preparations and backing or consumable inserts (if used) are free from scale, rust, oil, grease, and other loose surface materials. Any of these materials could cause inclusions or porosity in the weld.

During welding, slag formed by the welding process must be removed after each welding pass. Cleanliness inspections during welding confirm adequate removal of slag and use of proper cleaning tools. In general, brushes and picks used on carbon and low alloy steels should not be used on stainless steels and nickel and copper alloys. Such use can result in free iron contamination of the speciality metals.

Cleanliness inspections are also concerned with the environment. There should be no adjacent operations such as grinding that produce quantities of airborne materials that could violate the cleanliness requirement of the weld joint. Also, welding should not occur in open spaces during rain, snow and high winds. These natural elements can cause oxidation, porosity and cracking by addition of oxygen and hydrogen and by interfering with shielding.

Inspection for Fit-Up

Fit-up inspections are visual and dimensional inspections that check joint preparation, position, restraints, base metal identity, and filler material identity. The requirements of the job package give the acceptance criteria.

As described in Module 28-4, weld joint preparations and fit-up dimensions are specified by sketches or drawings that are part of or referenced by the welding procedure or work instruction. The fit-up inspection confirms proper joint preparation, fit-up, and alignment by visually and dimensionally inspecting each drawing attribute. Fit-up inspection also checks for compliance with requirements for

backing gas when used and it confirms that the fit-up has placed the weld in the specified welding position.

Visual inspection confirms compliance with specified requirements for distortion control devices. This includes clamps, braces, fixtures, and chill blocks. (When welding a thin member to a thicker member, chill blocks are placed against the thin member to dissipate heat. This reduces the tendency of the thinner member to warp. Chill blocks are typically solid copper blocks.)

Material identity is confirmed by visual inspection. Base metal identity may be ascertained from physical identity on the base metal or by paperwork accompanying the base metal. Filler material identity is physically on the filler material or its container or both. Module 28-8 gives detailed information on filler material identity.

Inspection for Welding Data

Inspections for welding data are visual inspections supplemented as necessary by measuring devices. These inspections check for compliance with the welding procedure specification.

Inspection of preheat and interpass temperature requires use of a temperature measuring device. Preheat temperature is measured on the base metal within about two inches or less of the next welding pass. Interpass temperature is measured on the previous welding pass immediately prior to depositing the next welding pass. The most commonly used inspection devices are contact pyrometers and temperature melting crayons.

Contact pyrometers are direct reading temperature gages. Placement of the sensor directly on the weld or adjacent base metal will give a temperature reading on the dial.

Temperature melting crayons are made of a composition that melts at a specified temperature. Manufacturers supply

these crayons in increments of 25°F. For example, a series of crayons may have melting temperatures of 250°F, 275°F, 300°F, 325°F, etc. When measuring preheat temperature, a crayon is selected whose melting temperature equals the specified minimum preheat temperature. For example, if minimum preheat is 300°F, a 300°F crayon would be selected. If the crayon melts when marked against the base metal, it is evident that base metal temperature is greater than the specified minimum. When measuring interpass temperature, a crayon is selected whose melting temperature is equal to the specified maximum interpass temperature. If the crayon does not melt, it is evident that interpass temperature is below the maximum limit. In either case, crayon melting is observed by no visible marking on the metal. If the crayon does not melt, it physically marks the metal similar to colored chalk marking on a chalkboard.

Visual inspections are made for the remainder of the specified welding data. These inspections check for compliance with requirements for current, voltage, polarity, shielding gas, bead sequence and oscillation, flux if used, and any other specified welding data. All of these checks can normally be made by visually observing the welding equipment, gas meters, and the weld. When welding equipment does not have integral voltmeters and ammeters (or if these meters are not in the calibration program), portable tong meters are used. Tong ammeters and voltmeters contain a coil that is clamped around the welding power cable. When welding current is applied, its magnetic field is detected by the coil and reads out on the tong meter as volts or amperes dependent on the type of tong meter.

Inspection of Post Weld Heat Treatment

When post weld heat treatment is required, a heat treatment procedure (or the heat treatment section of the

welding procedure specification) provides instructions for the heat treatment. These instructions typically specify the method of heating, maximum heat-up and cool-down rates, the heat treatment temperature range, and the time period for holding the weldment within the heat treatment temperature range. Visual inspections are employed to confirm compliance with these requirements.

The method of heating is specified in terms of a furnace to be used when the weld is transportable or a means of locally heating the weld. Electrical induction heating coils and gas torches are common methods of local heat treatments. Furnaces are typically electric or gas types to avoid a contaminating atmosphere in the furnace. Certain special alloys also require use of an inert gas atmosphere during heat treatment.

Heat treatment chart recorders are typically used to provide a permanent record of the heat treatment. These recorders are normally of the thermocouple-bridge type with automatic chart recorders as described in Course 3, Principles of Process Instrumentation. A typical heat treatment chart is illustrated in Figure 28-6-1.

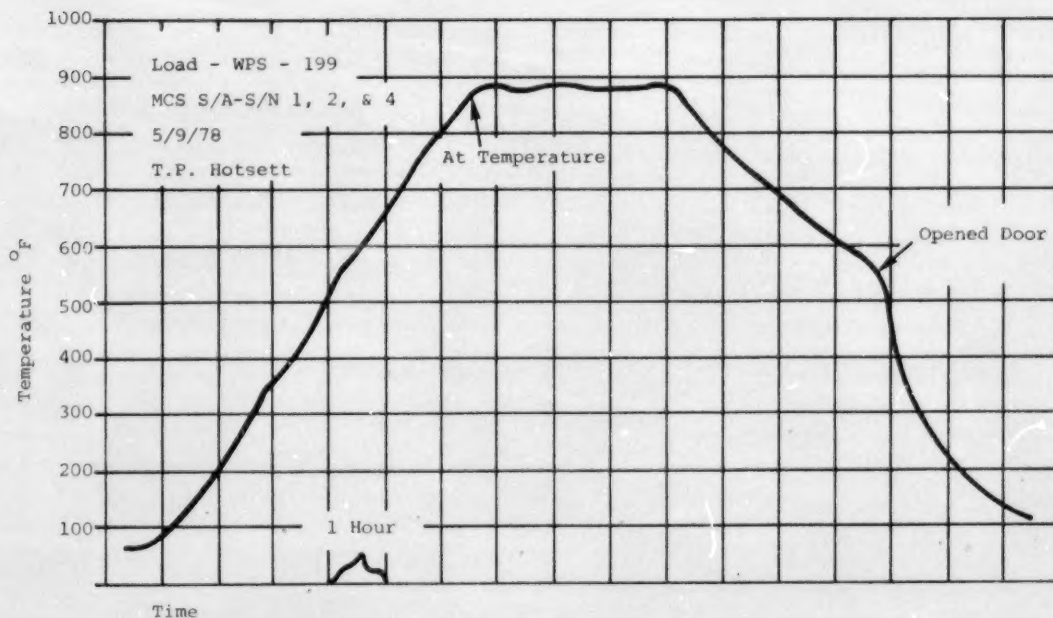


Figure 28-6-1. Typical Heat Treatment Chart

EXAMPLE REVIEW OF HEAT TREATMENT CHART

Given Procedural Requirements:

- Heat treat at 850-900°F for 1 hour per inch of thickness
- Maximum heat-up rate of 200°F/hour
- Maximum cool-down rate of 100°F/hour to 600°F

Review Using Figure 28-6-1:

1. From WPS-199 determine base metal thickness.
2. Base metal thickness = 2.75 inches.
3. Calculate time at temperature: $2.75 \times 1 = 2.75$ hours (minimum)
4. Read heat treat chart:
 - a. Temperature is between 880°F and 895°F for 3 hours - acceptable
 - b. Heat-up is from 70°F to 890°F in 5.5 hours
 - c. Calculate heat-up rate = $\frac{890 - 70}{5.5} = 149^\circ\text{F/hr}$ - acceptable
 - d. Cool-down is from 880°F to 600°F in 3.3 hours
 - e. Calculate cool-down rate: $\frac{880 - 600}{3.3} = 85^\circ\text{F/hr}$ - acceptable
5. Conclusion - Heat Treatment is Acceptable

Inspections for Compliance with Welding Program Procedures

In-process visual inspections determine that welding program procedural requirements are met. These checks confirm use of the specified welding procedure, qualification of procedure and welder, completeness of the job package, and proper provision for acceptance inspections and associated records.

ESTABLISHMENT OF PROCESS MONITORING

The previous discussion points out the features and attributes of welding that are checked (inspected) in-process, i.e., while welding operations are occurring. The important question becomes how many welding operations must be inspected in-process. The answer is not absolute; it depends. The questions must be answered in qualitative terms.

Consideration of All Other Controls

In the establishment of a process monitoring program, all other quality controls and the production schedule are considered. With respect to welding program controls, the following exist:

- Written procedure that delineates responsibilities for control of welding.
- Written procedures that direct the welders, grinders, heat treaters, etc., in all pertinent requirements for making a quality weld.
- Use of qualified welding procedure specifications.
- Use of qualified welders.
- Nondestructive examination of completed welds.
- Use of qualified personnel for nondestructive examination.
- Certain in-process inspection required by applicable welding codes, (e.g., review of heat treatment charts).

From the above, the logical conclusion is that the objective of process monitoring is to provide assurance that all of the welding program controls are in place and working. Such assurance would indicate that welding defects would be prevented or at least detected.

Consideration of the Production Rate

Next, consideration is given to how much assurance is needed. Again, the answer is not absolute. The amount of monitoring is continuously assessed and adjusted in proportion to the production rate and number of deficiencies that occur. The typical process monitoring program has a "base line" amount of monitoring with provision for increasing or decreasing this amount.

The base line amount of monitoring is predicated on the production rate and the reject rate. If hundreds of welds are made per week, the amount is relatively high. On the other hand, if few welds are made per week, the amount is low. If few welding defects are occurring, the amount in both cases is lower. In establishing the base line amount of monitoring, all welding stations, welding processes, and welders should be subject to monitoring. An example of establishing a base line amount of monitoring is given on the next three pages.

EXAMPLE ESTABLISHMENT OF BASE LINE MONITORING

Research of welding schedules determines that on the average, the welding rates in number of welds per week are as follows:

<u>WELDING PROCESS</u>	<u>WELDING STATIONS</u>					<u>Total</u>
	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>E</u>	
OAW	10	0	0	0	0	10
SMA	30	120	40	40	0	230
TIG	0	0	80	80	0	160
MIG	0	0	80	80	0	160
SAW	0	0	0	0	20	20
TOTAL	40	120	200	200	20	580

Research of the number of qualified welders gives:

<u>WORK SHIFT</u>	<u>WELDING PROCESS</u>					<u>Total</u>
	<u>OAW</u>	<u>SMA</u>	<u>TIG</u>	<u>MIG</u>	<u>SAW</u>	
1	2	6	4	4	4	20
2	0	2	4	4	0	10
3	0	2	4	4	0	10
TOTAL	2	10	12	12	4	40

Base Line Determination:

1. As a starting point, the objective of monitoring 10% of the welding operations is established.
2. Number to be monitored weekly based on welding schedules for each process: (10% of each)

OAW - 1	
SMA - 23	
MIG - 16	Total - 58
SAW - 2	
TIG - 16	

EXAMPLE ESTABLISHMENT OF BASE LINE MONITORING (Continued)

3. Distribution of monitoring to equally cover welders:

Number of Welders Per Process X Total Monitoring
Total Number of Welders

$$\text{OAW } \frac{2}{40} \times 58 = 2.9$$

$$\text{SMA } \frac{10}{40} \times 58 = 14.5$$

$$\text{TIG } \frac{12}{40} \times 58 = 17.4$$

$$\text{MIG } \frac{12}{40} \times 58 = 17.4$$

$$\text{SAW } \frac{4}{40} \times 58 = 5.8$$

Total 58

4. Distribution of monitoring to cover shifts in proportion to number of welders:

OAW 2.9 All 1st. Shift

$$\text{SMA } 14.5 \times \frac{6}{10} = 8.7 \text{ 1st. Shift}$$

$$14.5 \times \frac{2}{10} = 2.9 \text{ 2nd. Shift}$$

$$14.5 \times \frac{2}{10} = 2.9 \text{ 3rd. Shift}$$

$$\text{TIG } 17.4 \times \frac{4}{12} = 5.8 \text{ For Each Shift}$$

$$\text{MIG } 17.4 \times \frac{4}{12} = 5.8 \text{ For Each Shift}$$

SAW 5.8 All 1st. Shift

EXAMPLE ESTABLISHMENT OF BASE LINE MONITORING (Continued)

5. Rounding gives:

<u>Monitoring Per Week</u>						
<u>Shift</u>	<u>OAW</u>	<u>SMA</u>	<u>TIG</u>	<u>MIG</u>	<u>SAW</u>	<u>Total</u>
1	3	9	6	6	6	30
2	0	3	6	6	0	15
3	0	3	6	6	0	15
Total	3	15	18	18	6	60

6. Conclusions:

Monitoring 60 welding operations per week as distributed above gives:

- slightly more than 10% coverage of all welding operations
 - more than one monitoring per week of any given welder.
- This may be excessive.

Final Base Line:

If this is initial establishment of base line (no prior welding), the base line of 60 monitoring events per week distributed as in the above table is a good starting point.

If welding has been in progress for some time, the reject rates would be considered. For example, consider reject rates of 1% for OAW, 12% for SMA, 2% for TIG, 8% for MIG and 4% for SAW. Assuming the company's goals are to shoot for no more than a 4% reject rate, become very concerned at at 8% reject rate and extremely concerned with a 15% reject rate, adjustments to the base line are in order. Using these reject rates, the 60 monitoring events might be readjusted to provide:

<u>Monitoring Per Week</u>						
<u>Shift</u>	<u>OAW</u>	<u>SMA</u>	<u>TIG</u>	<u>MIG</u>	<u>SAW</u>	<u>Total</u>
1	1	15	2	8	4	30
2	0	5	2	8	0	15
3	0	5	2	8	0	15
Total	1	25	6	24	4	60

Analysis of Example Base Line Determination

The foregoing example of establishment of the amount of process monitoring illustrates that judgment is used. The 10% starting point is arbitrary but not unreasonable. The ratio of the number of monitoring events to the number of qualified welders is higher for OAW and SAW than for the other welding processes. A good reason for this higher ratio is not evident. This could have resulted in arbitrarily reducing the monitoring events for OAW and SAW. The redistribution of monitoring to take some attention away from the welding processes that have low reject rates and apply more attention to welding processes that have high reject rates involves judgment although statistical analysis could be accomplished for making such redistribution. (See Module 27-7)

Key features illustrated by the foregoing example and their merits are as follows; these four key features should be contained within every process monitoring program:

- All welding processes are subject to monitoring. Even when monitoring frequencies are redistributed, this key feature is retained. This provides at all times some amount of monitoring of each welding process to give potential for detecting deterioration in any process at an early stage should deterioration occur.
- All welders are subject to monitoring. This key feature is retained even when monitoring frequencies are redistributed. This provides for early monitoring of welders when they are assigned different welding operations.
- All shifts are subject to monitoring. This provides assurance that controls are working when the extra management and engineering support typically avail-

able on the day shift are not present.

- All welding stations are subject to monitoring. This provides assurance of compliance with welding controls regardless of where welding is performed.

ADMINISTRATIVE CONTROLS FOR PROCESS MONITORING

Implementation of the process monitoring program is more effective when written guidelines are employed. Due to the nature of process monitoring, these guidelines are not overly rigid. Since adjustments are frequently made in the program, the guidelines do not "spell out" all possible adjustments, but instead give responsibilities and criteria for determining and implementing the adjustments. The guideline procedure encompasses subjects to be monitored, designation of a responsible lead person, base line frequency, criteria for adjustments, check lists for each subject, provision for reporting results, and provisions for corrective action.

Guideline Procedure

Necessary administrative controls are established by the development of a single guideline procedure. This procedure is typically prepared by the Quality Assurance Department and implemented by the QA/QC Technicians assigned to the process monitoring function. It contains guidelines on seven elements as follows:

- Identification of Subjects to be Monitored - This module discusses subjects in terms of welding processes. Therefore, the subjects to be monitored are the welding processes employed. However, the process monitoring function can be applied to any activity that accomplishes the same type of task on

a frequent basis. In addition to welding, potential subjects include brazing, wiring, material issue and control, cleaning, testing, maintenance, operations, housekeeping, radiation protection, security, and safety.

- Identification of Base Line Monitoring Frequencies - For each subject to be monitored, a base line frequency is established as a target frequency. It is stated in terms of monitoring events per time period, e.g., 2 per week, 4 per two weeks, etc. This permits accomplishing the monitoring at any time within the time period. It permits the QA/QC Technician to select specific times within the time period when it is known that the subject process is underway. It permits redistribution of effort when warranted.
- Assignment of Responsibilities - A lead person (normally a supervisor) is assigned total responsibility for the monitoring program. This includes responsibilities for development of check lists, direction to technicians, adjustments to base line frequencies, and assuring effective and documented results. QA/QC Technicians are assigned responsibilities for performing process monitoring. This includes responsibilities for using check lists, documenting results, issuing corrective action requests on deficiencies found, and following up to insure implementation of corrective action.
- Listing of Criteria for Adjustment of Monitoring Frequency - The frequency of in-process monitoring requires periodic assessment to insure that a representative sample of production activity is obtained and that concentrated attention is given to problem areas. To accomplish these purposes, typical cri-

teria governing the frequency of process monitoring are:

- monitor at least between 5% and 10% of the welding operations for each welding process.
- monitor on each shift employing welding.
- monitor each qualified welder at least twice per month
- increase monitoring of any welding process whose reject rate exceeds 8%.
- provide full time monitoring of any welding process whose reject rate exceeds 15%.
- Use of Check Lists - The guideline procedure requires use of check lists as a guide to prevent overlooking key characteristics of welding operations during the monitoring function. Preparation of these check lists is discussed later in this module.
- Provisions for Reporting Results - A wide variation exists in industry practices with respect to reporting results of process monitoring because local management objectives may require little or considerable reporting. As a minimum, provision is made for recording the fact that welding operation was monitored as each monitoring activity is completed. Such record may be a log book, check-off on the monitoring schedule, or issuance of a special report. The primary purposes of this record are to provide objective evidence of the accomplishment of process monitoring and to compare accomplishments against schedule. Some companies employ additional record keeping practices to permit a trend analysis on the results. These records typically report total number of observations made, number of deficiencies found, hours expended in the monitoring activity, and a weighting factor that indicates the

relative significance of deficiencies found. These data permit trending such items as ratio of defectives to total observations, ratio of defectives to monitoring hours, and the same ratios weighted by relative significance of defectives. Regardless of the reporting method, another document (typically titled Corrective Action Request) is issued to responsible departments whenever a deficiency is found.

- Provisions for Corrective Action - Whenever the process monitoring function identifies a deficiency (e.g., failure to comply with procedures or welding codes), the department responsible for the welding operation is required to take corrective action. The process monitoring procedure typically provides for issuance of a Corrective Action Request (CAR) to the responsible department. The CAR identifies the welding operation, the deficiency, the date of discovery, the date by which correction is requested, and the preparer of the CAR. The responsible department determines action necessary to correct the specific deficiency and to prevent its recurrence. These are documented on the CAR which is then returned to the preparer. The preparer is typically responsible for following up to assure that the stated corrective actions have been taken and are effective.

Check Lists

Check lists for process monitoring can be generic in nature because welding processes employ the same type of characteristics in all applications. As long as all possible characteristics are included generically in the check list, the same check list can be used to monitor any appli-

cation of any welding process. However, when certain applications of a given welding process occur infrequently and such applications have unique requirements, it is typically best to prepare separate check lists for the infrequent and unique applications. Therefore, typical process monitoring programs include a check list for each of the "general" welding, hardsurfacing, seal welding, and tube-to-tube sheet welding.

Each check list serves to remind the monitor of key features (characteristics) to be checked. To determine specific requirements governing a particular characteristic, the monitor refers to the job package at the welding site. When it is recalled that the job package has been previously reviewed for compliance with the applicable welding code, it is evident that compliance with the job package equates to compliance with the welding code.

A typical check list for general welding is given in Table 28-6-1. This check list is suitable for monitoring OAW, SMA, TIG, MIG or SAW welding processes. Items on the check list that are not relevant to a specific welding process are simply considered not applicable.

TABLE 28-6-1

GENERAL WELDING MONITORING CHECK LIST

<u>Frequency:</u>	Established per Quality Procedure _____.
<u>Instructions:</u>	Each surveillance will check as many items on this check list as possible. More than one welding operation may be checked to complete all items. The applicable welding procedures shall be used as acceptance criteria. A _____ form will be issued for deficiencies noted.
<u>Check List:</u>	
A. Administrative Checks	
1. Correct welding procedure number and revision.	
2. Welding procedure is qualified.	
3. Welder is qualified.	
4. Job package is complete.	
B. Requirements Prior to Welding	
1. Correct joint design.	
2. Correct welding position.	
3. Correct fit-up and alignment (including backing or inserts as appropriate)	
4. Correct base material.	
5. Correct filler material.	
6. Cleanliness.	
7. Correct backing and flow.	
8. Correct preheat if required.	
9. Correct electrode.	
10. Record of inspection (where required)	
C. Requirements During Welding	
1. Correct type and polarity of current or fuel gas for OAW	
2. Correct current and voltage	
3. Correct type and flow of shielding gas	
4. Correct techniques.	
a. Position	
b. Tack welding	
c. Bead sequence and oscillation	
d. Interpass temperature if specified	
e. Crater fill or grinding	
f. Interpass cleaning	
g. Back gouging	
5. Proper provision for root and intermediate layer inspection where required.	
D. Requirements After Welding	
1. No visually discernable defects (under cut, burnthrough, excessive reinforcement, cracks, incomplete insert melting).	
2. Proper provision for post weld heat treatment.	
3. Proper provision for post weld inspection.	

WELD DEFECT ANALYSIS

Weld defect analysis uses acceptance inspection results to identify troublesome welds or welding processes. The defect analysis report identifies where additional effort is needed to reduce either the number or severity of welding defects. Essential elements of the defect analysis program are data collection, analysis, reporting and corrective action.

Data Collection

Since weld defect analysis is concerned with the ability to produce acceptable welds, the acceptance inspection results serve as the raw data to be collected. Acceptance inspection methods include visual inspection, magnetic particle testing, liquid penetrant testing, ultrasonic testing, and radiographic testing. (Module 28-7 describes the purposes and uses of acceptance inspections.) For weld defect analysis, it is sufficient to understand that each of these methods will report that a weld is accepted or rejected and for each rejection, the type of welding defect is reported.

In determining which of the available data to collect, a determination is made of the potential usefulness of the weld defect analysis program. If weld defects can be repaired cheaper than the cost of a weld defect analysis program, the program would not be particularly useful. Experience has shown that defects on the surface of the weld (e.g., excessive reinforcement, undercut, uncleanliness, pits at stops, crater cracks at stops, unfilled craters at stops, etc.) are quickly repaired with relatively little cost. On the other hand, defects in the weld metal and heat affected zone are more costly to repair. For this reason, visual, magnetic particle, and

liquid penetrant inspections, which detect surface defects, are typically not included in the data collection scheme. Instead, radiographic and ultrasonic testing reports serve as the raw data to be collected since these test methods detect subsurface defects.

Collection of raw data is accomplished by designating a copy of each radiographic and ultrasonic testing report to be issued to a central place for analysis. This copy is issued as soon as the report is generated (i.e., prior to any disposition of the report) to permit timely analysis. The Quality Assurance Department or the Welding Engineering Department may be the central collection agent responsible for weld defect analysis.

Dependent on the method of analysis, additional data may be collected, such as labor hours and size of defects.

Analysis

The method of analysis determines the usefulness of the results. If one were to speculate on what results might be desirable, the initial answer might be to identify the number of defective welds for each welding process. Such information would be more useful if it were also known how many total welds were made in the same time period. The ratio of these numbers gives a simple index for each welding process that indicates where the problems are in a broad sense. This simple method of analysis is illustrated in Example #1. (NOTE: Numerical values in all examples are for illustration only.)

EXAMPLE #1

WELD DEFECT ANALYSIS - SIMPLE METHOD

Method of Analysis:

$$\frac{\text{Number of defective welds per welding process}}{\text{Total number welds by that welding process}} \times 100 = \text{percent defective}$$

Examples:

$$\text{OA} \quad \frac{1}{3} = 33\%$$

$$\text{SMA} \quad \frac{27}{308} = 8.8\%$$

$$\text{SAW} \quad \frac{54}{84} = 64.3\%$$

Examination of Example #1 reveals that the results of this simple method may be misleading. While the submerged arc welding process is apparently giving unacceptable results, it is questionable whether the same conclusion applies to oxyacetylene welding. Also, the cost of repairing the 27 SMA defective welds could exceed the cost of repairing the 54 SAW defective welds. This simple method of analysis has inherent weaknesses of wide variance in percent defective without explanation.

Weaknesses of the simple method of analysis are mostly overcome by normalizing the data with labor hours. In this method, labor hours for making the weld and predicted labor hours for repairing the weld are collected. Predicted repair labor hours are collected to avoid waiting until repairs are actually made to make the analysis. Example #2 illustrates the labor hour method of analysis.

EXAMPLE #2

WELD DEFECT ANALYSIS - LABOR HOUR METHOD

Method of Analysis:

$$\frac{\text{No. Defective}}{\text{Total No.}} \times \frac{\text{Repair Hours}}{\text{Original Hours}} \times 100 = \text{percent defective}$$

Examples:

$$\text{OA} \quad \frac{1}{3} \times \frac{0.2}{1.5} \times 100 = 4.4\%$$

$$\text{SMA} \quad \frac{27}{308} \times \frac{54}{924} \times 100 = 0.5\%$$

$$\text{SAW} \quad \frac{54}{84} \times \frac{160}{336} \times 100 = 30.6\%$$

Examination of Example #2 reveals that the percent defective now represents both the number of defective welds and a measure of severity of the defects (expressed in the ratio of repair hours to original hours). This method identifies where largest repair costs exist and the results are, therefore, useful. A weakness lies in the ability to obtain accurate estimates of anticipated repair hours. These estimates can vary widely dependent on the experience of the persons making the estimates.

An indicator of severity of defects that does not have to be estimated can be obtained directly from acceptance inspection reports. This indicator is the size of the defect. Example #3 illustrates a defect analysis method that uses the ratio of defect length to total weld length.

EXAMPLE #3

WELD DEFECT ANALYSIS - LENGTH METHOD

Method of Analysis:

$$\frac{\text{No. Defects}}{\text{No. Welds}} \times \frac{\text{Total Defect Length}}{\text{Total Weld Length}} \times 100 = \text{Percent Defective}$$

Examples:

$$\text{OA} \quad \frac{1}{3} \times \frac{1}{9} \times 100 = 3.7\%$$

$$\text{SMA} \quad \frac{27}{308} \times \frac{100}{2500} \times 100 = 0.4\%$$

$$\text{SAW} \quad \frac{54}{84} \times \frac{900}{3300} \times 100 = 17.5\%$$

Comparison of Example #3 with Example #2 reveals that the same relationships are retained but SAW percent defective appears less severe in Example #3. The probable reason is the failure of the length method to consider the depth of the weld defect. Defects close to the surface are repaired more quickly (and less costly) than defects deep in the weld metal. This disadvantage can be overcome by using the volume method of analysis where the volume of repair is compared to the total volume of the weld. This method is illustrated in Example #4.

EXAMPLE #4

WELD DEFECT ANALYSIS - VOLUME METHOD

Method of Analysis:

$$\frac{\text{No. of Defects}}{\text{No. of Welds}} \times \frac{\text{Repair Volume}}{\text{Total Volume}} \times 100 = \text{Percent Defective}$$

Examples:

OA	$\frac{1}{3}$	$\times$	$\frac{0.5}{4.5}$	$\times$	100	=	3.7%
SMA	$\frac{27}{308}$	$\times$	$\frac{150}{1350}$	$\times$	100	=	0.9%
SAW	$\frac{54}{84}$	$\times$	$\frac{950}{2000}$	$\times$	100	=	30.5%

SUMMARY

Of the four methods described, the labor hour method and the volume method give the best indication of troublesome welding processes. Each uses a severity factor that is proportional to the amount of cost to repair the defects. The labor hour method has the disadvantage of being dependent on estimated repair hours. The volume method has the disadvantage of requiring considerable calculations to obtain repair and original volumes. Nonetheless, both of these methods enjoy widespread use where there are sufficient on-going welding operations to warrant a weld defect analysis program.

The simple method and the length method do not have good indicators of severity of weld defects. Nonetheless, these methods take little time to implement and are sometimes used when the number of on-going welding operations

is insufficient to warrant the more complicated methods.

Weld defect analysis is typically employed by component vendors where much of the processing is by welding. It is also sometimes employed during the construction phase of a nuclear power plant. The operations phase of a nuclear power plant typically does not have sufficient welding operations to warrant weld defect analysis.

Whenever a weld defect analysis program is used, more categories than welding processes are typically analyzed. Categories are selected that will best pinpoint where the problems are occurring. For example, the percent defective may be determined for either each welding station, each shift, each procedure (or some grouping of procedures), each type of application (e.g., pipe, plate, hardsurfacing, seals, etc.), each type of defect or some combination of these.

Report of Weld Defect Analysis

The report of weld defect analysis is most effective when it is user oriented. The individual who has made the analysis has collected hoards of data which of itself is of little interest to the persons responsible for reducing the weld defect rate. Such persons are interested in where the problems are and what are the probable causes.

Weld defect analysis cannot predict with much accuracy exactly what corrective action is necessary. Instead, the analysis identifies when and where corrective action is needed. Persons responsible for improving welding performance must evaluate for what actions are necessary. These evaluations consider amount of future welding to occur, causes of the previous defects, results of recent process monitoring and a current review of welding operations.

Since the weld defect analysis report is to be user oriented, it typically reports only the analysis results.

Typical data included in reports are given in Table 28-6-2.

TABLE 28-6-2

SAMPLE WELD DEFECT ANALYSIS REPORT

Week 42

Percent Defective:

PROCESS	Stations and Shifts								
	Shop A			Shop B			Shop C		
	1	2	3	1	2	3	1	2	3
OA	2.7	N/A	N/A	0.8	N/A	N/A	1.9	N/A	N/A
SMA	12.3	6.2	5.4	3.6	7.6	7.2	6.2	6.8	6.4
TIG	2.4	1.8	2.8	0.9	1.3	1.2	2.4	1.6	2.8
MIG	N/A	N/A	N/A	9.7	12.1	11.8	5.4	6.1	5.9
SAW	N/A	N/A	N/A	4.1	3.9	3.8	2.9	3.1	3.0

Types of Defects in Percent of Total:

OA incomplete fusion 88%, porosity 8%, others 4%

SMA slag 74%, incomplete fusion 17%, cracks 6%, others 3%

TIG incomplete fusion 51%, incomplete insert melting 40%, cracks 7%, others 2%

MIG cracks 67%, burnthrough 12%, incomplete fusion 11%, porosity 8%, others 2%

SAW burnthrough 71%, incomplete fusion 12%, slag 11%, others 6%

Instructions:

Recipients of this report are required by Procedure 1034.3 to take action as follows:

1. For percent defectives between 4% and 8%, take appropriate actions aimed toward reducing the percent defectives. These actions need not be documented.
2. For percent defectives exceeding 8%, respond to the undersigned within three days identifying corrective actions taken or planned.

(Signature)

Review of Table 28-6-2 identifies that the analyst has included types of defects as an aid to the recipients of the report in determining corrective action. For example, Shop A has a 12.3% defect rate for SMA on Shift 1. The analysis has indicated that the major cause of SMA defects is slag. Therefore, Shop A would consider interpass cleaning techniques as highly suspect.

In summary, the weld defect analysis program determines what data to collect, how to analyze the data, how to report the results, and when to take corrective actions. Either the labor hour method or the volume method gives best indication of problems. Identification of types of defects (or some other indicator of probable causes) in conjunction with percent defective permits the recipient of the report to intelligently assess the true causes of weld defects and to take effective corrective actions. In addition to periodic reports, such as that shown in Table 28-6-2, the results of each report can be graphed to show a longer term trend.



EXERCISES

The following exercises serve to reinforce the concepts covered in this module. The first three exercises refer to the MATERIALS, PROCEDURES and DATA TABLE listed in this module.

1. Obtain a copy of a company's procedures describing their welding program for monitoring of welding processes. Using this, evaluate these procedures to determine if

the key points of this module are included. (Refer to PROCEDURE Number 1 for further details.)

2. Obtain copies of actual heat treatment charts and corresponding procedural limits. Review each chart and determine if the procedural requirements were met as described in the PROCEDURES section of this module.
3. Using a copy of a company's procedure describing their weld defect analysis program and a copy of an analysis report, evaluate the procedure and the report using the information given. The PROCEDURES section of this module gives a suggestion for carrying out this exercise and a sample of welding data is included in the Data Table portion of this module.
4. The duties of the QA/QC Technician in monitoring of welding operations are performing inspections while using a check list as a guide, reporting results, issuing corrective action requests on deficiencies found and following up on implementation and effectiveness of corrective action. Briefly explain each duty.
5. Monitoring of welding operations provides an assurance that established welding program controls are in place and working. Briefly discuss how such a program can be carried out.
6. Inspections typically employed with monitoring welding operations are given in the following list. Briefly discuss each operation:
 - a. Cleanliness
 - b. Fit-up
 - c. Welding data review

- d. Post weld heat treatment
 - e. Program compliance
7. Essential elements of the Guideline Procedure for Welding Process Monitoring are given in the following list. Briefly explain each element of the guideline procedure listed.
- a. identification of subjects to be monitored
 - b. identification of base line frequency
 - c. assignment of responsibility
 - d. listing of criteria for adjusting the monitoring frequency
 - e. use of check lists
 - f. provisions for reporting results
 - g. provisions for corrective action
8. The welding process monitoring program should include provisions for periodically monitoring all:
- welding procedures
 - welders
 - welding shifts
 - welding stations
- Briefly explain how this monitoring should be carried out.
9. Of four methods of weld defect analysis described by this module, the labor hour method and volume method provide the best indicators of severity of welding defects. Briefly explain.



MATERIALS

The first three suggested exercises for this module involve (1) establishment of a welding process monitoring program, (2) interpretation of heat treatment charts, and (3) performing welding defect analysis. Supplementary materials for these exercises may be desirable as follows:

1. Copy of a company's procedures describing their welding program and their program for monitoring of welding processes. Students/trainees could be requested to evaluate these procedures to determine if key points in this module are included. (To be used for Exercise #1)
2. Copies of actual heat treatment charts and corresponding procedural limits are needed for this exercise. (To be used for Exercise #2)
3. Copy of a company's procedure describing their weld defect analysis program and copy of an analysis report. Students/trainees could be requested to evaluate the procedure and report in terms of the key features described by this module. (To be used for Exercise #3)



PROCEDURES

Using the MATERIALS suggested for this module and/or the information given here, perform the following PROCEDURES in completing the first three assigned EXERCISES.

Procedure #1:

This procedure is in reference to Exercise #1 and refers to the establishment of a Welding Process Monitoring

Program.

Given: Company XYZ performs welding on an on-going basis as follows:

<u>Shift</u>	<u>Welds Per Week/Number of Welders</u>				
	<u>OA</u>	<u>SMA</u>	<u>TIG</u>	<u>MIG</u>	<u>SAW</u>
1	100/15	500/60	15/5	10/5	0/0
2	0/0	200/25	15/5	10/5	0/0
3	0/0	200/25	15/5	10/5	0/0

Procedure:

Establish a base line frequency for monitoring the welding processes. Document all assumptions and calculations. Determine the minimum number of technicians necessary for implementing the monitoring program. (Use 40 hour work weeks, but with daily assignments on any shift. Assume Company XYZ works only five days per week. Assume it takes 2 labor hours for each individual monitoring activity including reporting and following up on corrective action.)

Procedure #2:

This procedure is in reference to Exercise #2 and refers to the review of heat treatment charts and procedures.

Given: Various heat treatment charts and corresponding procedural requirements given by the instructor.

Procedure: Review each chart and determine if the procedural requirements were met as evidenced by the chart. For any violation, describe the specific violation and discuss any actions taken.

Procedure #3:

This procedure is in reference to Exercise #3 and refers to the Evaluation of a weld defect analysis program.

Given: The collection of welding data listed in Table 28-6-3 in the DATA TABLE section of this module.

Problem: For each welding process, calculate percent defective using simple, labor hour, length and volume methods. Graph the results of each method. State which method appears to be most representative and why. Determine what adjustment, if any, you would make to the process monitoring schedule determined in Exercise #1. Give rationale for any changes.



DATA TABLE

TABLE 28-6-2

WELDING DATA FOR EXERCISE #3						
DAY	SHIFT	NO. WELDS	NO.	LABOR HR.	LENGTH	VOLUME
			DEFECTS	RATIO	RATIO	RATIO
1	1	20(OA)	2	112/8	200/4	75/3
		100(SMA)	45	390/90	1500/180	800/185
		3(TIG)	0	40/0	125/0	100/0
		2(MIG)	2	32/8	600/100	450/60
1	2	40(SMA)	30	170/30	400/60	125/15
		3(TIG)	1	38/2	115/3	90/1

		2 (MIG)	0	40/0	550/0	400/0
1	3	40 (SMA)	10	150/50	325/40	100/40
		3 (TIG)	0	40/0	115/0	85/0
		2 (MIG)	1	32/8	550/20	400/25
2	1	20 (OA)	3	112/8	190/3	70/2
		100 (SMA)	22	420/60	1700/175	825/90
		3 (TIG)	1	36/4	90/10	80/6
		2 (MIG)	1	28/12	490/50	300/90
2	2	40 (SMA)	15	184/16	420/20	140/10
		3 (TIG)	0	40/0	120/0	90/0
		2 (MIG)	1	16/24	300/200	200/300
2	3	44 (SMA)	10	192/8	500/20	900/30
		4 (TIG)	1	36/4	114/4	100/3
		2 (MIG)	2	32/8	425/20	280/12
3	1	20 (OA)	0	120/0	200/0	80/0
		100 (SMA)	12	440/40	2000/135	900/110
		2 (TIG)	0	40/0	85/0	60/0
		2 (MIG)	1	36/4	450/10	325/8
3	2	40 (SMA)	6	188/12	400/6	150/8
		3 (TIG)	0	40/0	120/0	85/0
		2 (MIG)	1	36/4	420/8	300/6
3	3	36 (SMA)	8	180/40	425/30	825/130
		2 (TIG)	1	32/8	110/30	80/20
		2 (MIG)	1	28/12	400/10	250/90



REFERENCE MATERIALS

American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, Section III, New York, NY

American Welding Society, Structural Welding Code, AWS D1.1, New York, NY



TEST

1. Name the primary objective of a welding process monitoring program.

2. Name four key features of the welding process monitoring program.

a.

b.

c.

d.

3. Name seven elements of the Guideline Procedure for the welding process monitoring program.

a.

b.

c.

d.

e.

f.

g.

4. Describe how one generic check list can be used for monitoring any welding process.

5. Process control typically consists of procedures review, process monitoring and defect analysis. Briefly define each of these terms.
6. Weld defect analysis is warranted when the on-going amount of welding operations give good potential for overall cost savings through the ability of the analysis to reduce the defect rates. List the type of welding data that should be collected to properly carry out a weld defect analysis program.